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UNITED STATES BUREAU OF MINES
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MINING METHODS OF THE BUNKER HILL AND SULLIVAN MINING AND CONCENTRATING CO., KELLOGG, IDAHO

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MINING METHODS OF THE BUNKER HILL AND SULLIVAN MINING AND CONCENTRATING CO., KELLOGG, IDAHO[1]

By U. E. Brown[2]

INTRODUCTION

This paper[3] describing the mining methods employed by the Bunker Hill and Sullivan Mining and Concentrating Co. at Kellogg, Idaho, is one of a series being prepared by the United States Bureau of Mines on mining practices, methods, and costs in the United States.

The Bunker Hill and Sullivan mines are situated in the western part of the Coeur d'Alene district at Kellogg, Shoshone County, Idaho. The mines were discovered during the summer of 1885 and except for two short periods of labor trouble, between 1890 and 1900, have been in continuous operation. About 575 men are employed at the mine. The production is about 1,400 tons of lead-silver ore per day. This is treated in the company's concentrator and smelter at Kellogg.

The mines are notable, among other features, for two quite outstanding conditions: Uniformity of ore analysis, both as to metallic mineral and gangue rock, and great irregularity of ore occurrence. Ore bodies are never found just where they are expected, nor are the outlines of the ore bodies the same on adjoining levels. There is a certain rough alignment but never any distinct continuity of form. On the other hand the quality of the ore, both as to lead and silver content, has been surprisingly uniform from the top of the mountain where mining was first done over 40 years ago to the bottom of the mine over a mile away on the axis of the ore shoot; the valuable minerals have been accompanied by siderite and silicious material in rather uniform proportions throughout the whole of the area.

The failure to apply the shrinkage, caving, or top slicing methods to these rather large bodies of ore may be surprising to those who have had successful experience with such systems of ore extraction. The mining methods employed, however, have been found to be exactly suited to the irregular occurrence of the ore bodies. At the Bunker Hill the ore is too high grade to risk wasting. The method used permits not only very clean mining but very complete extraction at minimum cost; no ore need be overlooked or wasted. Mining costs probably could be lowered by applying shrinkage methods to some of the ore bodies, but on the other hand this would result in dilution because of the poorly defined and soft walls, and the certain leaving of important masses of ore in the walls.

The stoping methods now used were developed about 15 years ago. The mining of the ore on the hanging wall is done at the peak of the stope with a nearly vertical working face of ore. This is contrasted with the older method of stoping with a flat back, resulting in unavoidable heavy falls of ore and waste, danger to workmen, and certain loss of mineral. The adoption of the present form of stoping with the inverted cross-V section has resulted in a greatly reduced rate of accidents to workmen and the practical elimination of the caving of stopes.

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[1] - The Bureau of Mines will welcome reprinting of this paper, provided the following footnote acknowledgment is used: "Reprinted from U. S. Bureau of Mines Information Circular 6407."

[2] - Chief engineer, Bunker Hill and Sullivan Mining and Concentrating Co.

[3] - Written under the direction of Stanley A. Easton, vice-president and manager, Bunker Hill and Sullivan Mining and Concentrating Co., and one of the consulting engineers, U. S. Bureau of Mines.

ACKNOWLEDGMENTS

Acknowledgments and thanks for assistance in the preparation of this paper are due to Stanley A. Easton, vice-president and manager, and Wm. McDougall, superintendent, of the Bunker Hill and Sullivan mines. The author also acknowledges the aid of H. M. Childs, O. H. Hershey, and J. S. Marshall.

GEOLOGY

The ore bodies of the Bunker Hill and Sullivan mine occur in a severely faulted zone of Algonkian quartzites and have been much disturbed by later faults. Although the metamorphism of the region is attributed to underlying intrusives, no connection between these intrusives and the deposition of the ore has been shown.

The ore bodies occur in two types of veins: The Bunker Hill vein and the Jersey fissure. The Bunker Hill type consists of wide irregular masses of galena with siderite and quartz gangue. There is ordinarily one fairly well defined wall, but never two. The dip is between 40 and 50°. About 80 per cent of the ore has been produced from this type of vein. Veins of the Jersey fissure type vary in width from a few inches up to 40 feet and have a dip from 45 to 50°. They carry some siderite but the ore is silicious as compared to the ore of the Bunker Hill type veins. The Jersey veins traverse hard quartzite.

The ore minerals in the mine are galena carrying silver and associated zinc minerals.

DEVELOPMENT

Mining operations are conducted through the Kellogg tunnel which is the No. 9 level of the mine. No. 1 shaft, through which the ore is hoisted, is sunk from the tunnel at a point 10,000 feet from the portal. This shaft is an incline, sunk in the footwall of the ore bodies at an angle of 50° from the horizontal.

No. 2 shaft is 600 feet from the collar of No. 1 shaft and is parallel to it in course, but has an inclination of 40° 35'. This shaft has been constructed by raising from each level in turn to connect with the bottom of the shaft at the level above. No. 2 is a service shaft and no ore is hoisted through it.

No. 1 shaft contains three compartments, two hoisting compartments, each 5 by 5 feet 6 inches and the third for manway and pipes 5 feet 6 inches square. When sinking, three miners drill a round on night shift. Shoveling and timbering are done on day shift. The broken material is removed by a small hoist temporarily installed on the lowest station. The raise from the station under the shaft, shown in Figure 1, is used as a storage and reloading chute for the broken rock from the shaft. Figure 2 illustrates the shaft round. The shaft timbering is shown in Figures 4 a and 4 b.

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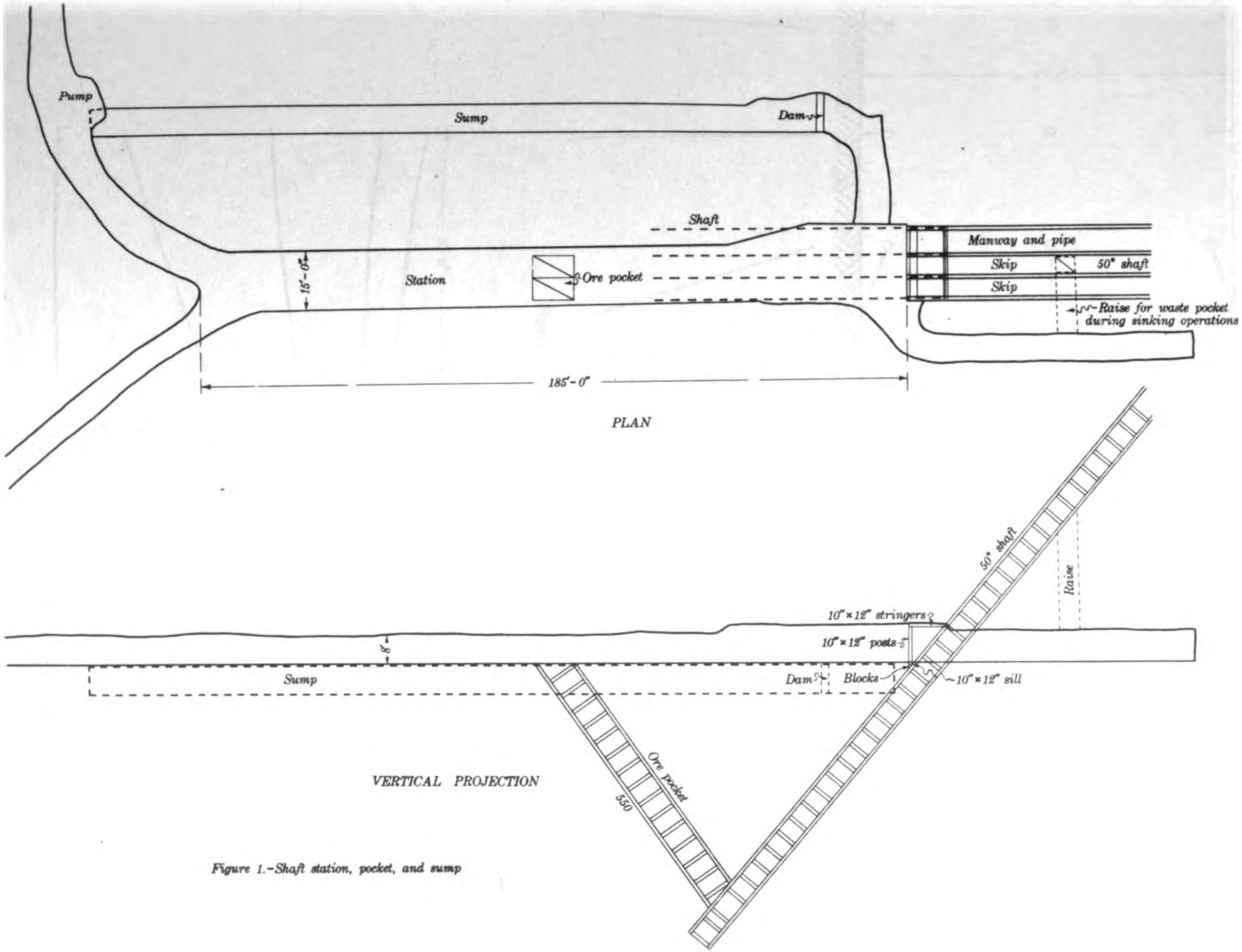

Figure 1.-Shaft station, pocket, and sump

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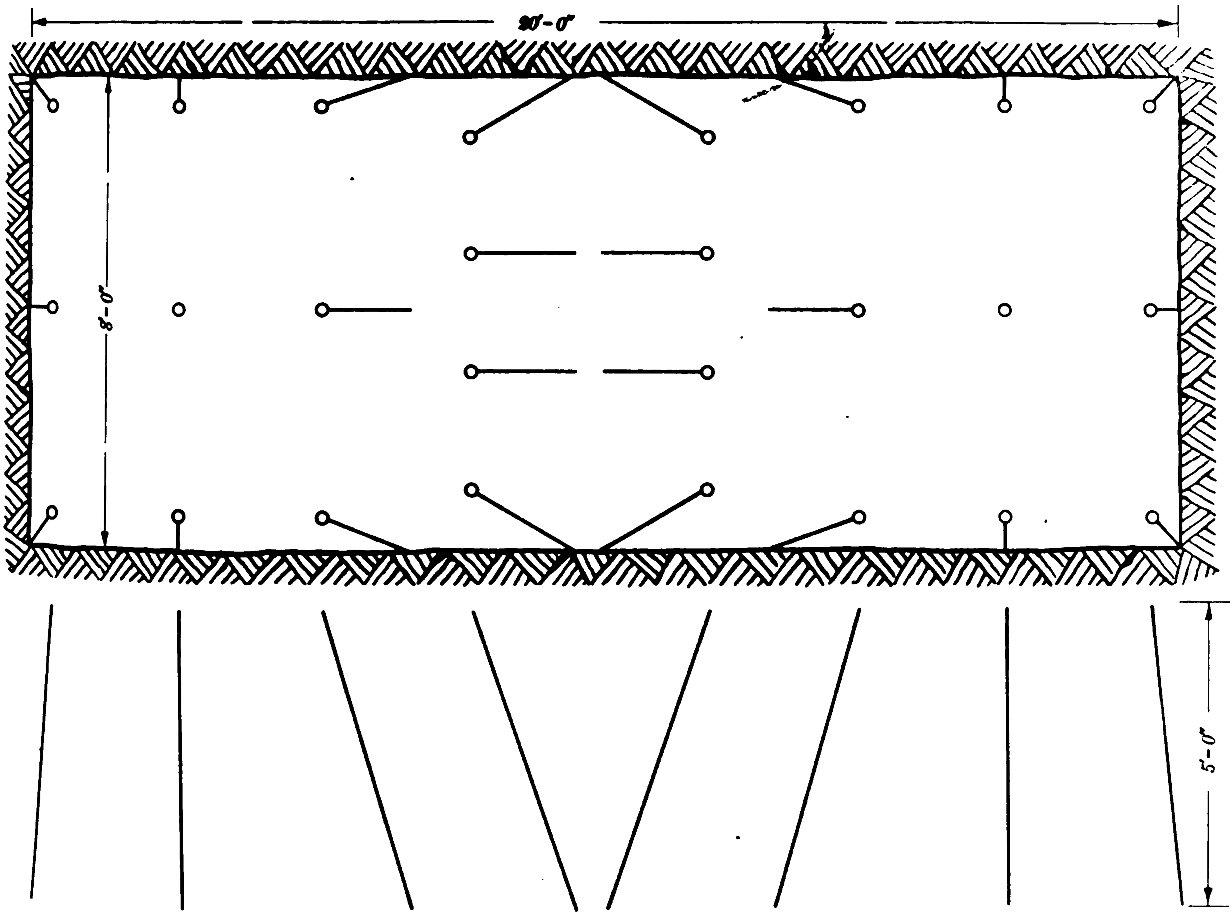

Figure 2.-Standard shaft round of 26 holes

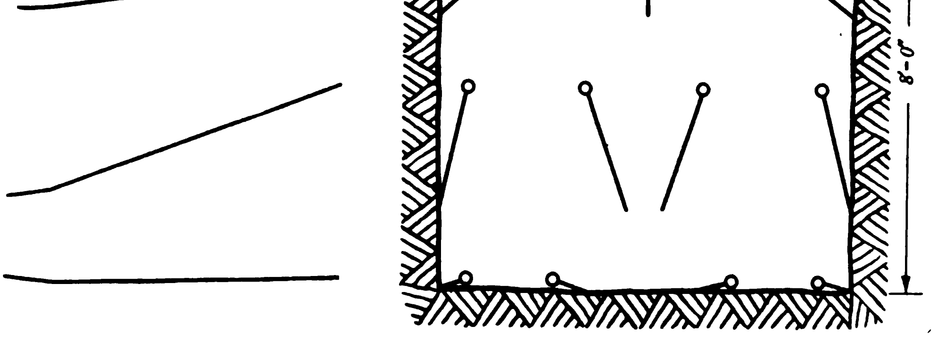

Figure 3.-Standard 14-hole drift round

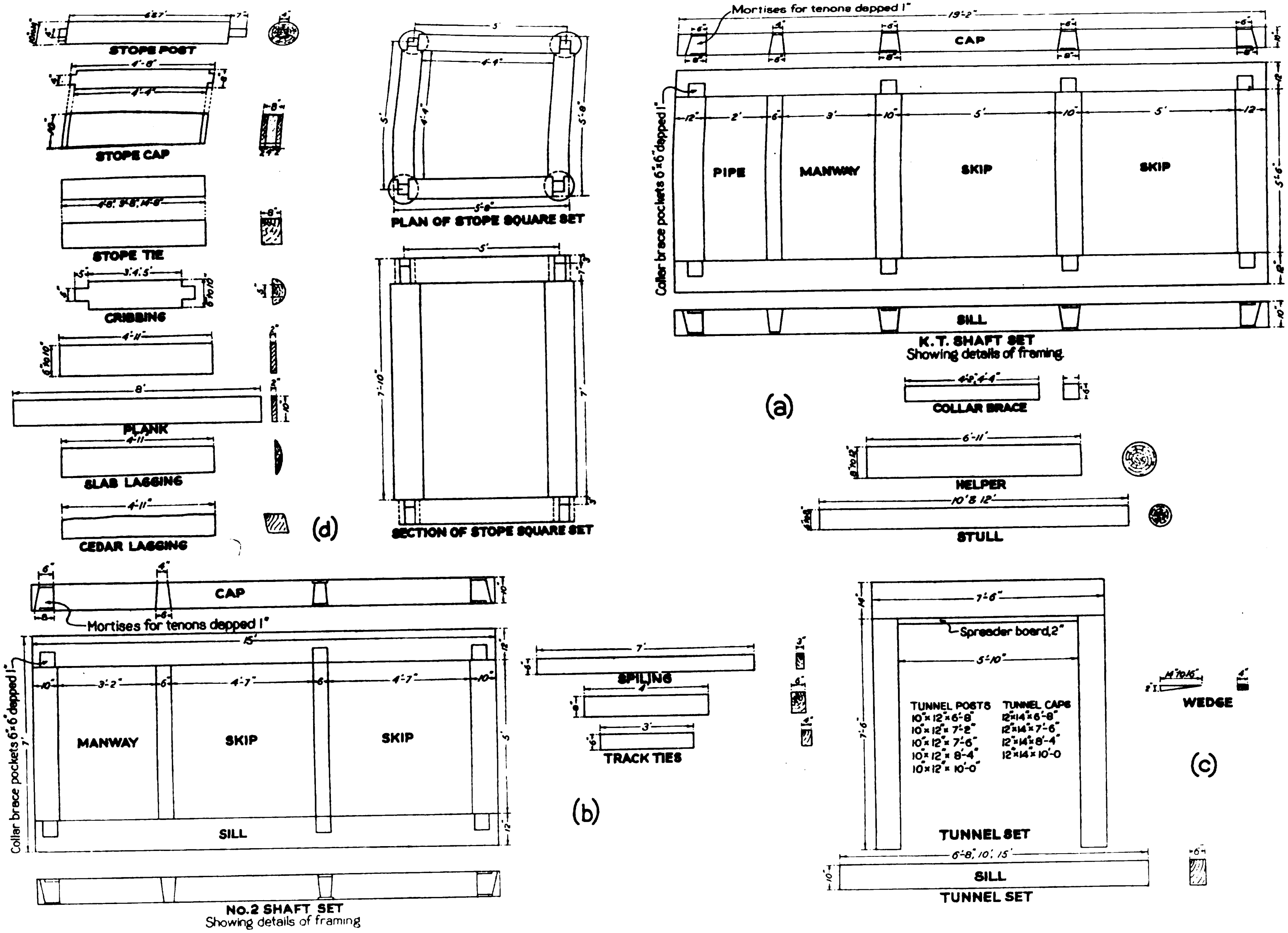

Figure 4.- Timbering details

Levels 10 to 19, inclusive, are driven from No. 1 shaft at vertical intervals of 200 feet. To open a new level, the first step is to sink No. 1 shaft to a point 90 feet below the elevation of the level to be opened. When sinking is finished, the station is cut on the same course as the shaft (fig. 1). The first 50 feet is driven 20 feet wide. It is then narrowed to 15 feet and continued to a point 185 feet from the shaft. Crosscuts are then started at the end of the station. One is driven to the right to intersect the Bunker Hill vein and one to the left to a point from which is cut the station for the raise to the bottom of No. 2 shaft. This crosscut intersects the Jersey type veins. While crosscutting is in progress a loading pocket and sump are cut.

The pocket is a 55° raise, run from the shaft starting 75 feet below the station floor. It opens into the station 90 feet from the shaft. It is timbered with 10 by 10 inch posts 7 feet long and 10 by 12 inch caps and sills 10 feet long, divided into two compartments and lined with 3-inch planks.

The sump is a drift driven from the shaft 8 feet below the station. When the drift has advanced 35 feet it is turned and continued parallel with the station until it connects with the bottom of the crosscut to the right. A pump station is then cut at this intersection, and a concrete dam is built at the turn.

Drift rounds are ordinarily drilled by one man. If the ground is very hard two machines may be necessary. Drilling is done on day shift and shoveling at night. Figure 3 shows the standard 14-hole drift round. Figure 4 c shows a tunnel set.

STOPING

The hard quartzite in which the Jersey veins are found allows these ore bodies to be mined by a cut-and-fill method with cribbed chutes and manways. The ore is always blasted on plank floors covered with fine waste to prevent loss of fines. The broken ore is shoveled into wheelbarrows and coarse waste is thrown out by a sorter. The coarse waste is used to build up walls, behind which the finer material is thrown. These walls also restrict the scattering of ore during blasting. Sorting not only enriches the mill feed but furnishes a part of the necessary filling for the stope.

When the ore has been removed a sufficient height above the floor, the chutes and manways are built up by additional rounds of cribbing and the plank flooring is taken up. The stope is then filled to about 5 feet below the back. This is done either by blasting down rock from the hanging wall or by running waste into the stope through a raise to the level above.

Chutes are spaced 15 feet to 20 feet apart, are built of 10-inch half-round cribbing flat side in, and lined with plank or sometimes steel plate where abrasion is severe. The manways are spaced 50 feet apart and are built of 10-inch half-round cribbing, round side in.

When stoping is begun, a raise is driven from about the middle of the stope, following the footwall to the level above. This raise serves the stope as a pass for tools, timber, and waste and for ventilation. When the stope is halfway to the level above, the raise is used as a passage for the miners.

Ordinarily very little timber is needed but when necessary the hanging wall is supported by stulls and headboards, or occasionally by stulls and wall-plates. If the stope becomes very wide or if a section of soft ground is encountered, square-sets are used.

When the back of the stope is 24 feet from the level above, tightly filled square-sets replace the stulls. In this way the drift over the stope can be kept open with little trouble.

In mining the large irregular masses of Bunker Hill type ore, the square-set and fill method is used. The practice is to remove all material showing any galena. extremely low-grade ore is therefore sometimes mined but by so doing high-grade ore is often uncovered. Ordinarily one well defined wall is found; sometimes there is no wall, but there are never two. No two cross sections even when close together are alike. The ore bodies range from 300 to 1,000 feet in length and from 30 to 125 feet in width. Stoping has been continuous from the outcrop at an elevation of 3,800 feet above sea level to No. 19, the lowest level now open, at an elevation of 400 feet above sea level or a distance of about 5,000 feet on the dip.

Although a definite hanging wall is seldom found, the rock over the ore will be termed the hanging wall. This is invariably heavy, and the use of square-sets closely filled with waste is the only method by which it can be safely supported. As rapidly as the ore is removed, square-sets are erected, and as soon as convenient these sets are tightly lagged with slabs and filled with waste.

Square-set timbers consist of light 12-inch round posts and 8 by 10 inch caps and ties, framed as shown in Figure 4 d. This method of framing has the advantage that one member of the set, the tie, is unframed. The small tenons or horns on the posts would appear to be a point of weakness, but little trouble is experienced from that source. The post is primarily to support vertical pressure, whereas side pressure from the walls is resisted by the caps and ties. The ties, being unframed and stronger than the caps, are placed parallel to the strike of the walls and the caps at right angles to it. These square-sets, with a covering of 2-inch plank, serve to prevent sloughing of ore from the face, protect the miners, and retain the waste. Neither these nor any heavier timbers alone could support the mass of the hanging wall.

The method of stoping now in use has evolved from the flat-back stope shown in Figure 5 through the low flat arch shown in Figure 7 to the high sharp arch of Figure 6.

The vein is cut by the crosscut from the shaft and a drift run on the footwall to the extremities of the ore body. When the ore widens so that it can not all be included in the drift, crosscuts are driven at intervals to the limit of the ore on the hanging-wall side. (See fig. 9.)

Stoping is started on the hanging-wall side of the vein. This is shown in plan and section by Figures 8 and 14. Sills covered with slabs are laid and square-set timbers placed These are extended and the back row filled to support the wall. A new floor is started above the sill floor, the first row of square-sets extending into the hanging wall to obtain filling for the sill floor, after which stoping progresses toward the footwall. A steeply arched back is maintained at all times. From the footwall drift, at about the center of the ore shoot, a raise is started on the footwall to the level above. When this raise has "holed through," it is timbered with 6-foot posts and 10-foot caps to provide a waste pass and a timber pass with a manway between. Air and water lines enter the stope through the manway.

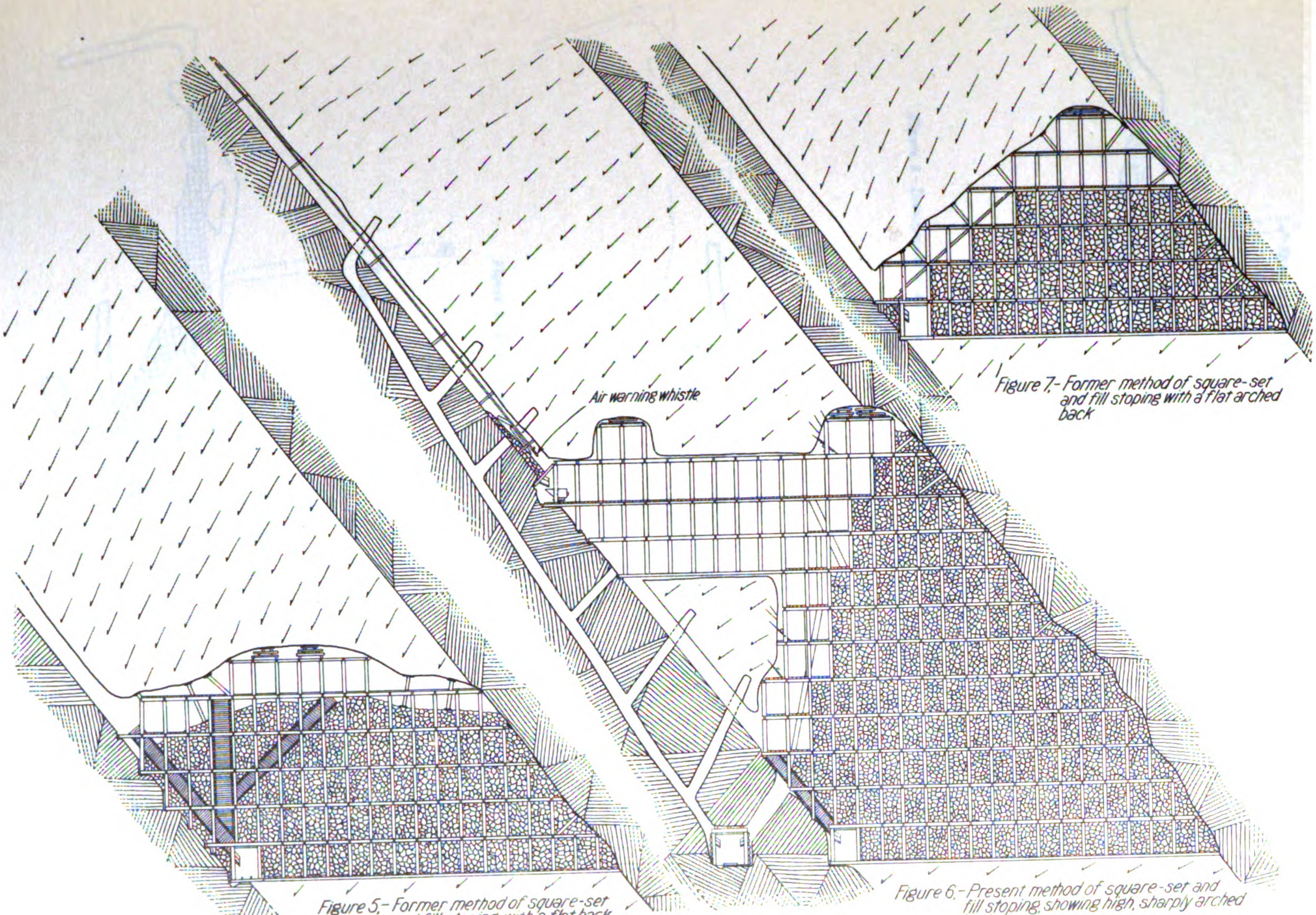

Figure 7.- Former method of square-set and fill stoping with a flat arched back

Figure 5.- Former method of square-set and fill stoping with a flat back

Figure 6.- Present method of square-set and fill stoping, showing high, sharply arched back

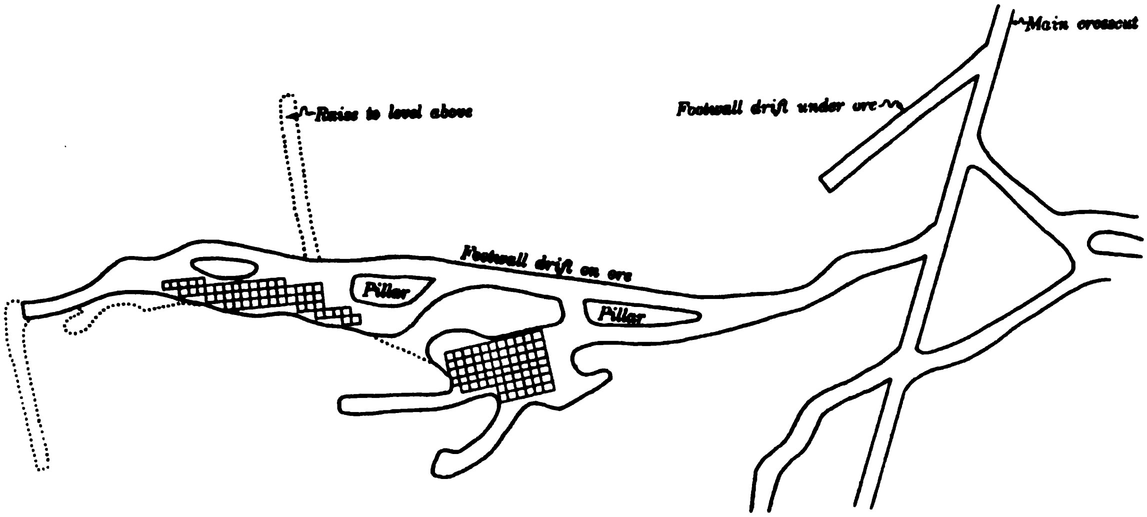

Figure 8.–Development of sill floor, showing start of raise to level above, and foot-wall drift under ore

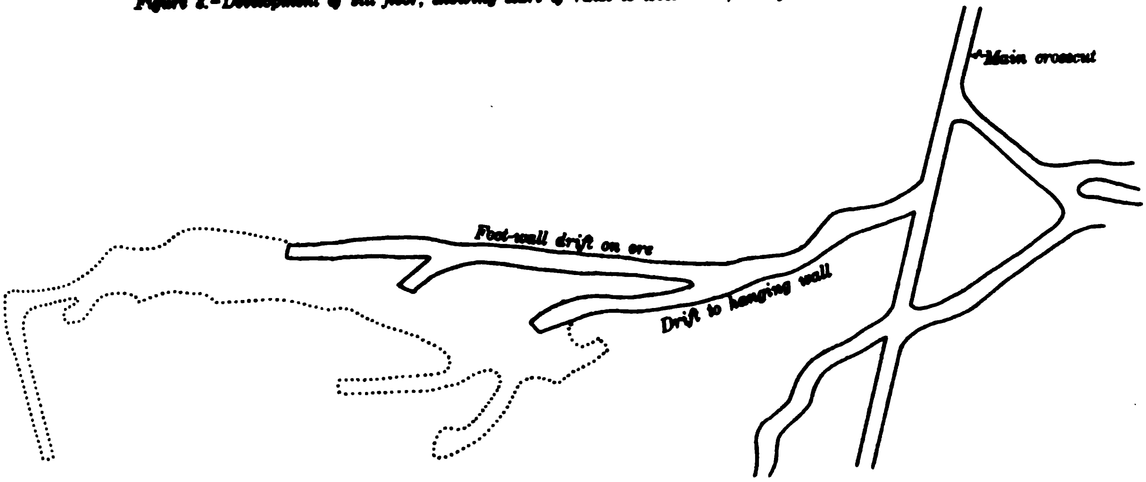

Figure 9.–Drifting on ore body, showing drifts to hanging wall

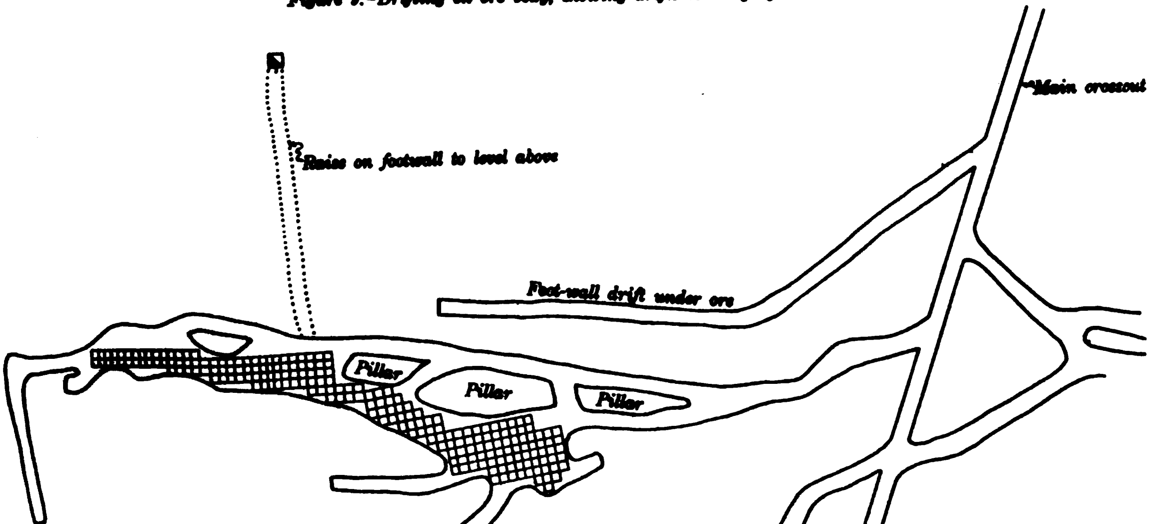

Figure 10.–Further development of sill floor, with square-set advance

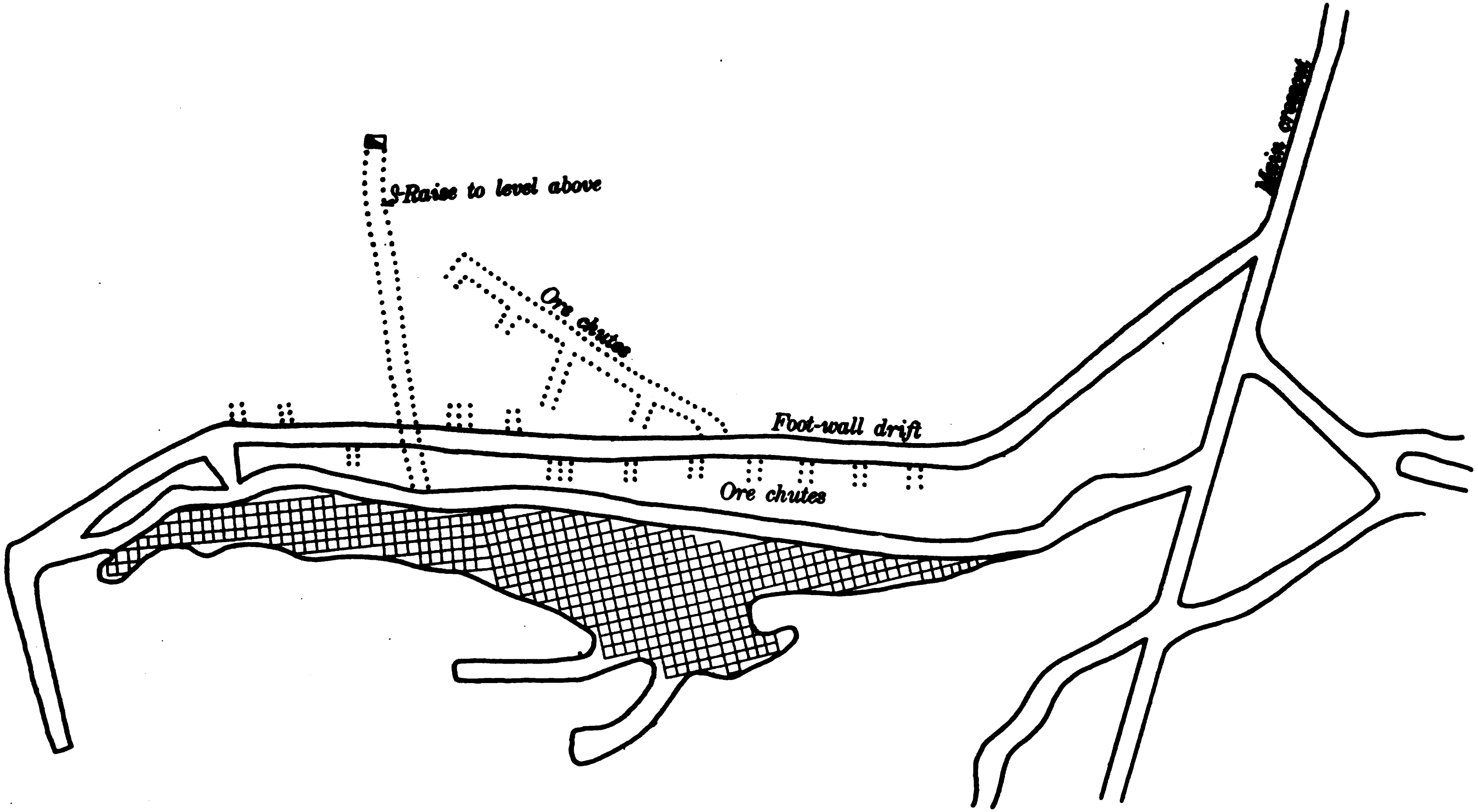

Figure 11.-Complete development of sill floor, showing ore chutes for higher floors

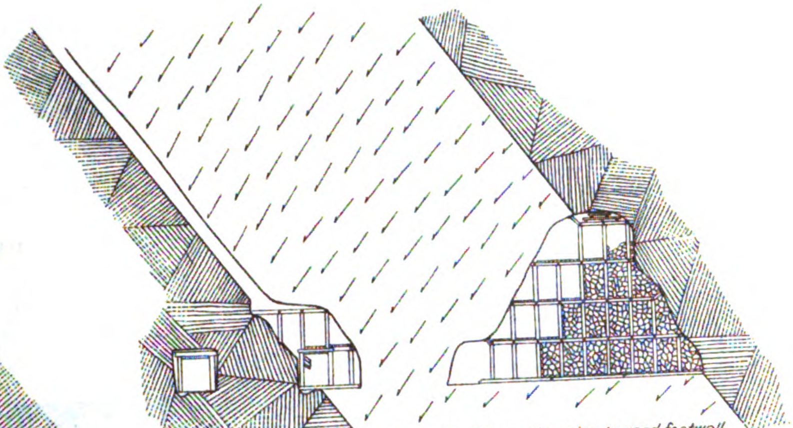

Figure 12.- Stope advancing toward footwall, raise completed, and main haulage drift advancing under footwall. Note steep face of stope

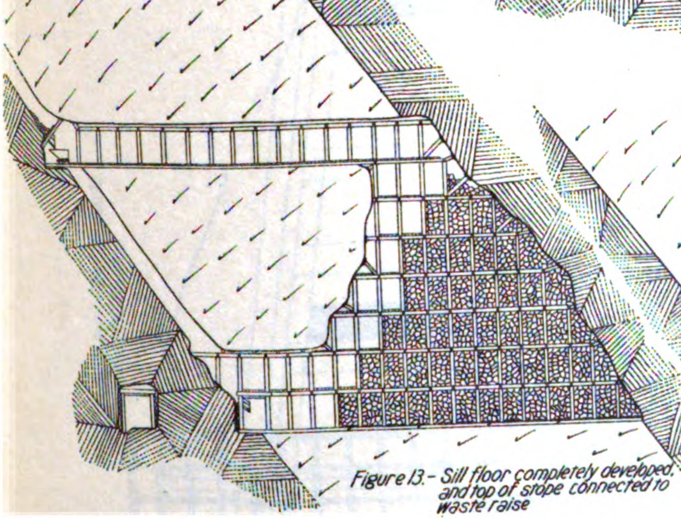

Figure 13.- Sill floor completely developed, and top of stope connected to waste raise

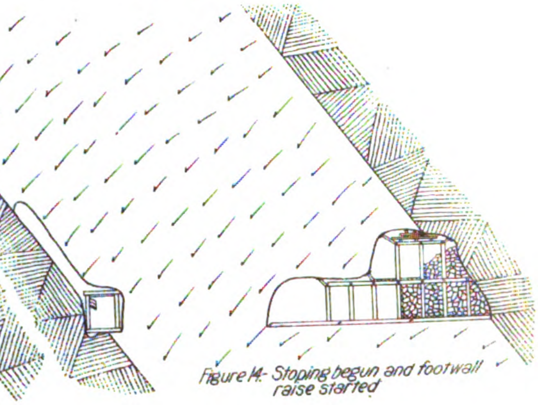

Figure 14.- Stoping begun and footwall raise started

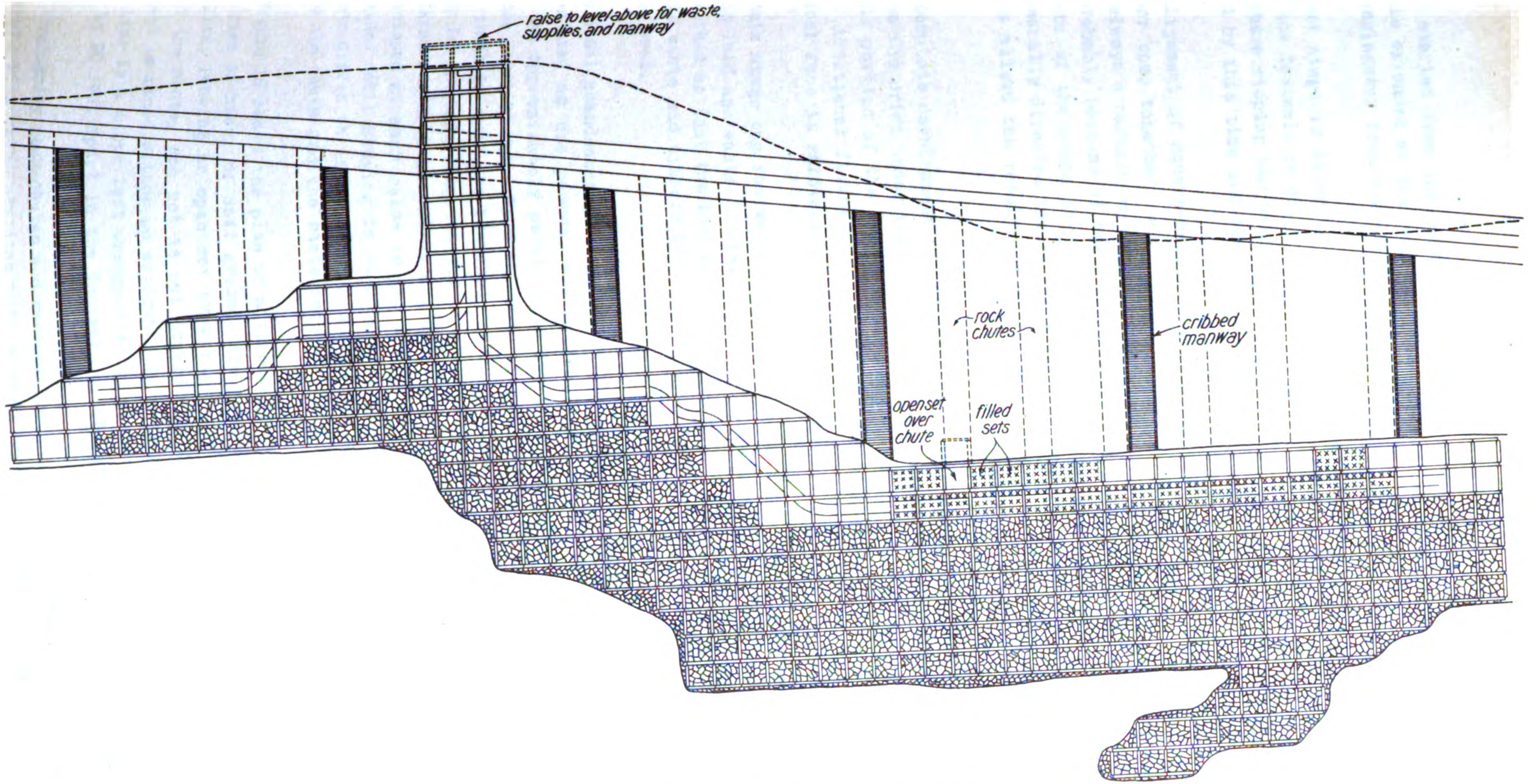

Figure 15.- Plan of a typical floor

Another drift is started from the shaft crosscut and driven about 20 or 30 feet under the footwall. This is extended at the same time that stoping is being started, and finally becomes the main haulageway from the stope.

The next stage is shown by Figures 10 and 12. The footwall raise is completed. The drift under the footwall is being extended. The pillars of ore are being attacked. The various places where stoping has been started are joined. The first footwall drift is generally completed by this time and the boundaries of the ore body have been determined.

The alignment of square-sets may be imperfect where the several stoping sections on the sill floor come together, but this is considered an advantage. In a large timbered stope there is always a certain amount of longitudinal pressure as well as transverse pressure. This is probably because of the great weight of the hanging wall. It may not be evident in all parts of the stope nor always exerted in the same direction, though it is believed to be generally directed toward the wider parts of the stope. A change in the alignment of the sets allows the resultants of any such pressure to be taken up by the walls of the stope.

The complete development of the sill floor is shown by Figures 11 and 13. Chutes are started from the drift under the footwall toward the ore, at intervals of 15 to 20 feet. The hanging-wall portion of the stope is advanced by mining nearly vertical slices, one or two sets wide. Additional floors are opened to keep a strong arch over the stoped area, and a nearly vertical face is maintained.

At this stage the footwall raise is connected by a row of square-sets with the top floor; track is laid and waste is drawn from the raise and distributed by hand-trammed cars. The stope is worked so that the highest part is at the raise, thence sloping down to each end. This allows the waste and timbers brought in through the raise to descend to the place where they are to be used.

The final abandonment of the sill floor is shown by Figures 6 and 10. One or more raises, to be used as ore passes, are driven from the haulage drift under the footwall. These raises are approximately parallel to the footwall and intersect the ore a short distance under the level above. From the main raises, branch raises are driven to the ore, and if necessary these in turn are branched. This eliminates the use of long cribbed chutes, or the necessity for transferring the ore on an intermediate level. If the stope is very long, additional three-compartment raises are driven on the footwall to the level above, and the stope is developed at each raise in the manner already described. Such additional raises, not being needed until stoping is in progress, start on one of the higher floors from a row of square-sets driven to the footwall. Figure 6 also shows the temporary slides used to get the ore into the chute and the waste into the sets being filled.

Figure 15 shows the plan of a floor and illustrates the method of distributing the waste. In case of heavy or soft ground, the square-sets at the face are lagged with slabs and are filled, leaving an open set over the chute as shown by the dotted area. From the open set at the chute, one set is cut toward the footwall and a section as many sets long as convenient is mined either up or down. In bad ground, filled and open spaces alternate, and at no time is a stope left unsupported by waste filling. Figure 15 also shows the rock chutes 15 to 20 feet apart in the footwall of the stope and cribbed manways 50 feet apart.

Ordinarily rock chutes and manways are not cribbed unless bad ground is encountered. However, if a raise contains both a chute and a manway, each is cribbed separately;

the short raises driven from the haulage brift under the footwall to the stope are usually cribbed throughout.

Figure 6 illustrates the advantages found in mining by vertical slices. Drilling of the ore by uppers is much easier than by flat holes. The ore when blasted falls into the chutes. When sorting is necessary the ore is blasted on floors. The waste comes into the stope about the consistency of wet concrete. It thus settles in the lagged square-sets to a compact mass, forming a very solid wall to support the stope. The lagged and tightly filled sets being kept close to the face limit the area in which blasted ore may be scattered. Good protection is provided for the miners. Ventilation is better through vertical openings than in flat stopes. The high, sharp arch throws the weight of the ore on the footwall and the weight of the hanging wall on the solidly filled square-sets. This arch is developed early in the operation and carefully maintained until the stope is finished. The haulageway being in solid rock is not subject to settling. Rock chutes give greater storage capacity than timbered ones and require little repair.

Waste for stope filling is an essential for the vertical slice system of stoping and a supply must be available at all times. The supply of waste is derived from exploratory drifts and crosscuts, from sinking in No. 1 shaft or from raising No. 2 shaft. If necessary, waste raises are driven. These raises are driven into faulted zones where caving can be utilized.

For storage and distribution of this waste a series of connected raises known as the Newgard raise has been driven from No. 17 level to the Kellogg tunnel. Waste can be stored in the raise below any level or withdrawn from the section above for distribution.

Waste is transported to and from the Newgard Raise by the ore train drawn by a storage-battery locomotive.

Underground Transportation

Ore and waste are hoisted in skips of 10,000 pounds capacity.

The main hoist has a double drum with both drums clutched. The drum face is 5 feet, 6 inches and the diameter 8 feet. The hoist is driven by two 2,200-volt, 60-cycle, 300-horsepower, variable-speed motors, with liquid rheostat control. For deceleration when lowering men, dynamic braking is used. The maximum rope speed is 1,000 per minute. For men, under safety control operation, the maximum speed is 500 feet per minute. The cable is the Lang lay type, of plow steel, 1 1/8 inches in diameter. The hoist was built in 1923 at Wallace, Idaho.

The Kellogg tunnel is the main haulageway of the mine. The ore is delivered to the rock house by trains of eighteen 3-ton Bunker Hill cars (fig. 16). The trains are drawn by 8-ton, 500-volt trolley locomotives. On the levels below the tunnel, 2-ton Bunker Hill cars are used. These trains are drawn by storage-battery locomotives.

Figure 17 shows a standard chute for loading ore into cars.

Pumping

Water is pumped through No. 1 shaft to the Kellogg tunnel. Pumps are multiple stage turbines, direct-connected to motors. Approximately 1,000,000 gallons of water is pumped daily.

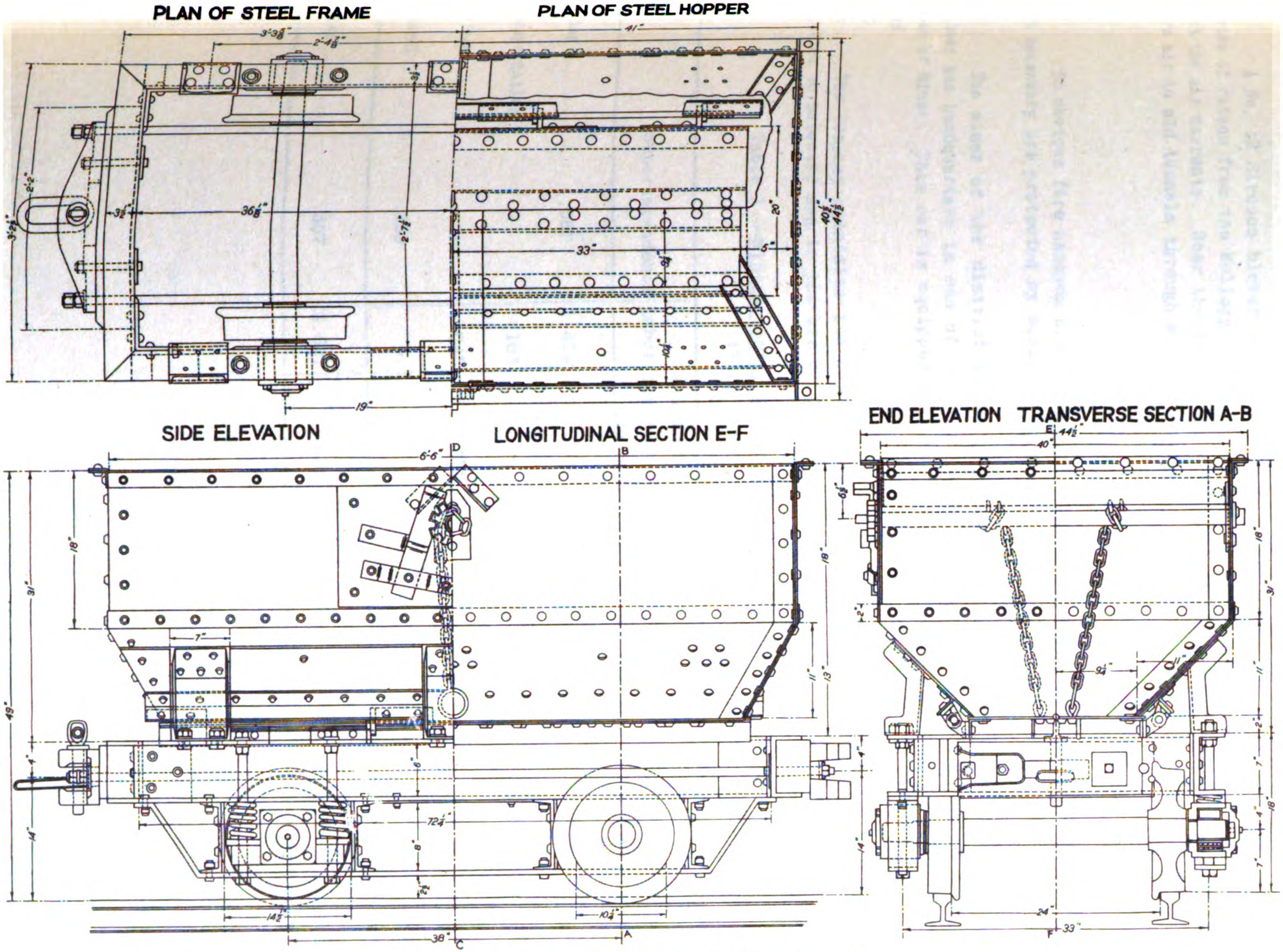

Figure 16.- Bunker Hill 3-ton ore car

VENTILATION

A No. 12 Sirocco blower forces 40,000 cubic feet per minute of air down through a series of raises from the Kellogg tunnel to the No. 16 level. Doors on the various levels direct the air currents. Near the top of No. 2 shaft two No. 10 Sirocco Blowers deliver the return air to old tunnels through which it escapes.

FIRE HAZARDS

No obvious fire hazards are allowed to exist in the mine. Electrical installations where necessary are protected by concrete or metal.

The mines of the district maintain a safety engineer in Wallace, Idaho. This engineer has headquarters in one of the older type of mine-rescue cars, procured from the Bureau of Mines. This car is equipped with the necessary mine-rescue apparatus and accessories.

The company maintains its own equipment. The safety engineer gives weekly instruction to selected men in the use of the mine-rescue apparatus and in first aid.

Table 1.—Mining costs, Bunker Hill and Sullivan mines, 1928
(Tons mined - 452,345)

	Superintendence	Labor	Ventilation, compressed air and power	Explosives	Timber	Other supplies	Total
Mining	.057	1.419	.209	.167	.321	.241	2.414
Transportation	-	.163	-	-	-	.088	.251
Surface	-	.045	.020	-	-	.130	.195
General	.250	-	-	-	-	.787	1.037
Total	.307	1.627	.229	.167	.321	1.246	3.897

Table 2.--Details of exploration, stoping, and mining costs,

Bunker Hill and Sullivan mines, 1928

Exploration	
Details	Cost per foot
Machinemen	.67
Miners	2.64
Shovelers	.45
Carmen and trammers	.22
Timbermen	1.03
Powder	2.06
Caps and fuse	.35
Illuminants	.03
Timber	.46
Miscellaneous supplies	2.27
Machine shop repairs	.04
Tool shop repairs	.43
Compressed air	.70
Surveying	.08
Total	11.43

Stoping	
Details	Cost per ton
Shift bosses	.068
Machinemen	.224
Miners	.242
Shovelers	.507
Carmen and trammers	.068
Motormen	.057
Timbermen	.296
Hoistmen and skipmen	.005
Nippers and supplymen	.040
Powder	.125
Fuse and caps	.029
Illuminants	.009
Timber	.315
Miscellaneous	.155
Machine shop repairs	.049
Electric repairs	.012
Tool shop repairs	.023
Electric power	.009
Compressed air	.101
Surveying	.007
Ventilation	.020
Total	2.361

Table 2.—Details of exploration, stoping, and mining costs, Bunker Hill and Sullivan mines, 1928–Continued

Mining	
Details	Cost per ton
Superintendent and foreman	$.031
Shift bosses	.068
Machinemen	.228
Miners	.258
Shovelers	.509
Carmen and trainmen	.069
Motormen	.057
Timbermen	.313
Hoistmen and skipmen	.037
Pumpmen	.022
Nippers and supplymen	.063
Repairmen	.003
Timekeepers	.012
Powder	.136
Fuse and caps	.031
Illuminants	.009
Timber	.321
Miscellaneous supplies	.232
Machine shop repairs	.066
Electrical repairs	.028
Building repairs	.011
Tool shop repairs	.025
Electric power	.076
Compressed air	.105
Electric light	.007
Heating	.020
Surveying	.026
Train service	.024
Tramming ore	.056
Tramming men into mine	.003
Tramming supplies into mine	.005
Contingent expense	.107
Depreciation	.349
Administrative expense	.238
Taxes and insurance	.275
Fire protection	.002
Ventilation	.021
Mine accidents	.054
Total	3.897

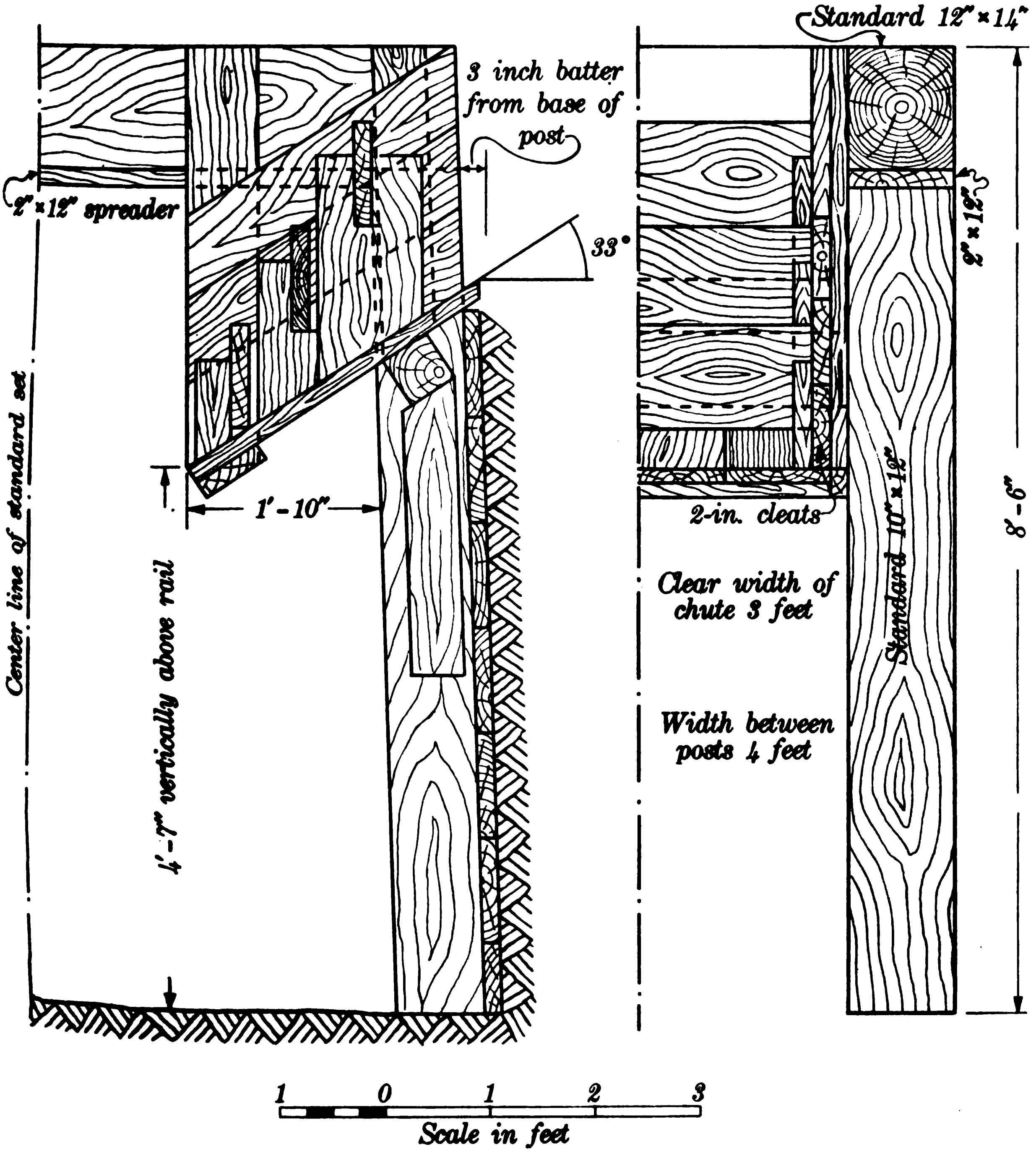
3 inch batter from base of post
2" × 12" spreader
33°
Center line of standard set
4'-7" vertically above rail
1'-10"
Standard 12" × 14"
2" × 12"
2-in. cleats
Clear width of chute 3 feet
Width between posts 4 feet
Standard 10" × 12"
8'-6"
1
0
1
2
3
Scale in feet

Figure 17.–Standard Bunker Hill and Sullivan chute

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